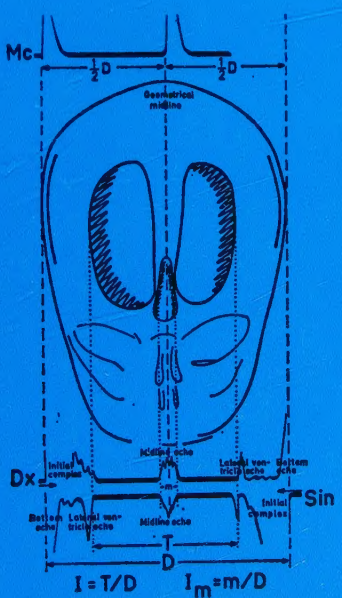
FROM THE SECTION OF PAEDIATRIC NEUROLOGY (HEAD: ASSOCIATE PROF. BENGT HAGBERG) AT THE DEPARTMENT OF PAEDIATRICS (HEAD: PROF. BO VALQUIST) UNIVERSITY HOSPITAL, UPPSALA, SWEDEN

ECHOENCEPHALOGRAPHY

IN PAEDIATRIC PRACTICE WITH SPECIAL REGARD TO MEASUREMENT OF THE VENTRICULAR SIZE



BY

IRÉNE SJÖGREN

1968

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From the section of Paediatric Neurology (Head: Associate Professor Bengt Hagberg) at the Department of Paediatrics (Head: Professor Bo Vahlquist), University Hospital, Uppsala, Sweden

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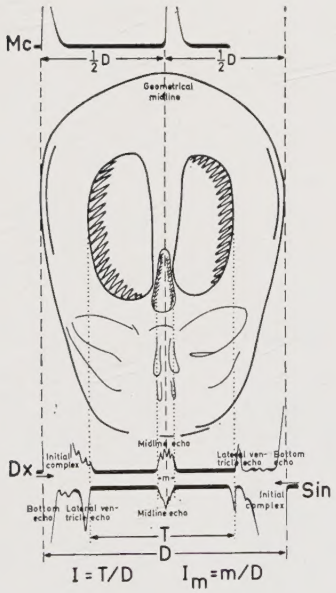


UPPSALA 1968

STOCKHOLM 1968. KUNGL. BOKTRYCKERIET P. A. NORSTEDT & SÖNER

Science

in a way is a play of adults.
It may be deadly serious
in its aims and methods,
but it means the same combination
of imagination and toys
as does the play of the child
and at its best
it gives the same satisfaction.
The toys of science
— may they be ideas
or may they be gadgets —
should continuously be improved
and exchanged.

Bo Wahlquist

This review is based on the following communications, which will be referred to by their capital letters as designated below.

A. Echoencephalography in paediatric practice with special regard to measurement of the ventricular size.
Part one: Some physical properties of ultrasound.
Acta Paediatrica Scandinavica, Suppl. 178, 1967

B. Echoencephalography in paediatric practice with special regard to measurement of the ventricular size.
Part two: Method and methodological difficulties.
Acta Paediatrica Scandinavica, Suppl. 178, 1967

C. Echoencephalography in infants and children.
Part one: Comparison between echoventriculography (EVG) and cerebral pneumography in 56 patients with normal or symmetrically dilated lateral ventricles.
Acta Radiologica, Suppl. 278, 1968
With K. Bergström and H. Lodin

D. Echoencephalography in infants and children.
Part two: Comparison between echoencephalography and cerebral pneumography in 14 patients with cerebral malformations.
Acta Radiologica, Suppl. 278, 1968
With K. Bergström and H. Lodin

E. Echoencephalography in 100 normal infants and children.
Submitted for publication in American Journal of Diseases of Children, 1968

Reprinted from Developmental Medicine and Child Neurology Vol. 10. No. 2. April 1968.

Echoencephalographic Measurement of Ventricular Size in Children

Irĕne Sjögren

Introduction

For several decades the ultrasound method has been used for technical and maritime as well as medical purposes (Dussik 1942, Ballantine *et al.* 1950, 1954, French *et al.* 1950, 1951, Edler and Hertz 1954). However, it was of great importance for the development of ultrasound diagnostics in the field of neurology, when Leksell in 1955 presented an echo method by which intracranial expansivities could be diagnosed through the intact skull; this method has been developed further by Leksell (1958) and Jeppsson (1961), and echoencephalography is now in routine use in neurodiagnostic centres all over the world. Leksell (1955/56) also considered it possible to diagnose infantile hydrocephalus by ultrasonic echoes, and both Jeppsson (1961) and Lithander (1961) showed that it was possible to detect echoes from the interface between the cerebrospinal fluid (CSF) and the cerebral parenchyma.

Many publications (reviewed by Grossman 1966, Schiefer and Kazner 1967, Pia and Geletneky 1968) have since described echoencephalographic findings similar to those reported by Jeppsson (1961).

Most authors, however, seem to have used the method only on available clinical material—*i.e.*, on patients with various cerebral disorders. Some new experience has been gained in this way, but no fundamental advances have been reported (Platt 1968). Few efforts seem to have been made to develop the method further in order to eliminate the technical difficulties and sources of error which were pointed out by Jeppsson (1961) and which confront every examiner. The theoretically simple echoencephalographic method is not simple in practice, particularly in examinations of the ventricular system, because of the complex anatomical construction of the human brain.

The aim of the present study was to summarize some of the diagnostic experience gained up to now with echoencephalography in infants and children, especially in the measurement of ventricular size, including my own experiences based on about a 1,000 echoencephalographic examinations done in the last five years (Sjögren 1963, 1964, 1965, 1967, 1968). The aims of these investigations were:

(1) to decide whether or not echoencephalography is harmless for newborn babies and to ascertain whether

From the Section of Child Neurology (Head: Associate Professor Bengt Hagberg) at the Department of Paediatrics (Head: Professor Bo Vahlquist), University Hospital, Uppsala, Sweden.

some of the difficulties, based on the physical laws of radiation and geometry, could reasonably be eliminated;

(2) to develop an echoencephalographic method suitable for determining the ventricular size in infants, with special consideration of the difficulties mentioned above;

(3) to compare the results of echoencephalographic measurements of ventricular size with similar results from cerebral pneumography, to obtain an idea of the method's reliability;

(4) to estimate the possibilities of diagnosing cerebral malformations and to ascertain whether the representation of the ventricular system in two or three dimensions, constructed from data obtained by echoencephalography was reliable;

(5) to measure the ventricular size in normal infants and children and to compare the results in different age-groups.

Definitions

Echoencephalography is the term introduced by Leksell (1955/56) for 'the diagnosis of intracranial lesions through the intact skull' by 'ultrasonic testing'; this term is applied here to the whole procedure, as well as to any single examination. The result of each examination is referred to as an *echoencephalogram*.

The combined photographic recording of a midline control and the echoencephalograms from the right and left test points, including also the above mentioned 'third ventricle check', is called an *echoventriculogram* (EVG) (see Fig. 2); the whole procedure is called *echoventriculography* or 'the EVG method'.

A. Some Physical Aspects of Ultrasound

Ultrasound is defined as sound waves with frequencies lying above the human audible range—*i.e.*, exceeding 18–20 kc./sec.; in the examinations described here, frequencies of 2 and 4 Mc./sec. were used.

As with audible sound waves, ultrasound requires a medium through which it can propagate; this may be a gas, a fluid or a solid body.

As with wave movements in general, ultrasonic waves transport energy. The ultrasound used for diagnostic purposes is emitted in short intense pulses separated by resting periods, which gives a low mean intensity.

Earlier investigations (Barth and Bülow 1949, Hüter 1954, Jeppsson 1961), as well as calculations with regard to thermal, mechanical and molecular effects (Sjögren 1967*a*) have shown that the energy transferred to the tissues during a diagnostic ultrasonic echo examination (A-scan) is considerably below the level at which harmful effects may occur, even in newborn babies.

Ultrasound can be directed as an almost parallel beam. When an ultrasonic beam is transmitted into the body and encounters an interface between tissues with different acoustic impedance (sound velocity $\times$ density), part of the ultrasound is reflected against the surface. Ultrasound reflected in this way gives rise to echoes. The reflection of ultrasound is determined by the general laws of radiation; thus the angle of reflection is equal to the angle of incidence. Reflection from a plane surface lying parallel to the surface of the probe gives rise to an ideal echo, rising almost at a right angle to the time axis; reflection from a plane surface positioned at a small angle to the surface of the probe may give rise to a wide and multi-spiked echo. If reflection occurs from a spherical surface, the amplitude of the echo increases with the curvature radius of the surface—*e.g.*, dilated lateral ventricle (see Fig. 1 B and C)—since the returning intensities are proportional to the effective transmitting surface, and the amplitudes are propor-

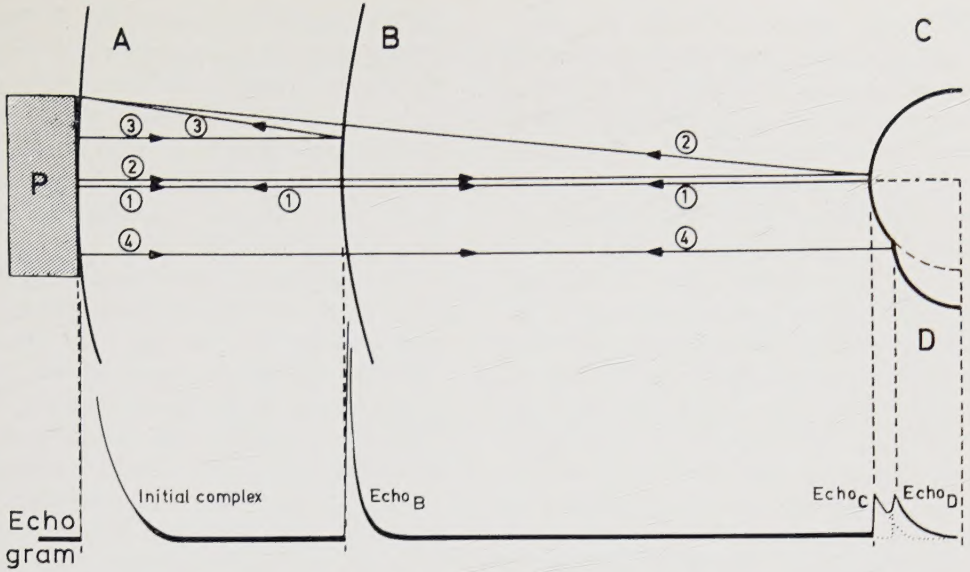


Fig. 1. Amplitude of the echo as a function of the radius of curvature of the reflecting surface, and demonstration of multi-peaked wide echoes. P = the probe, held closely against a spherical surface (A) (*cf.* an infant's head) from which a parallel ultrasound beam is transmitted; in its path, the beam encounters a spherical surface (B) (*cf.* a dilated lateral ventricle) and (C) which is contiguous to a curved surface (D) (*cf.* a small lateral ventricle or a dilated third ventricle). Ray 1 is the central ray which falls at right angles to both B and C; the reflected ultrasound returns to the same point on P from which it was transmitted. Ray 2 is the marginal beam which falls against C at such an angle that the reflected ultrasound returns to within the outer margin of P. Ray 3 is the marginal beam when reflection occurs against B. Ray 4 is a ray which falls at right angles to D; the reflected ultrasound returns to the same point on P from which it was transmitted.

tional to the square root of the intensities. A reflecting surface of irregular configuration may give echoes that are multi-spiked and increased in width—*e.g.*, small ventricles with irregularly formed surfaces (Fig. 1 C and D)—because of some differences in distance from the probe to different parts of the irregularly formed reflecting surface. Echoes from parallel ultrasound, transmitted from the same probe at the same distance from a curved reflecting surface, will be of higher amplitude when the reflecting surface is positioned so that it is concave, than when it is convex (see Fig. 1), because of the focusing properties of the concave surface.

When a wave motion traverses a medium, some absorption always takes place. When a sound wave penetrates a body containing interfaces between different media, a great part of the incident intensity is absorbed on traversing the material and large reductions in intensity occur at the reflecting echo-producing interfaces. The absorption losses increase greatly with increasing skull thickness. If both the absorption coefficients and the acoustic impedances are known for the different media, the intensity of both the penetrating and the reflecting sound waves can be calculated in every point of the body. Such calculations (Jeppsson 1961, Sjögren 1967*a*) show that echoes from the interface between cerebrospinal fluid and cerebral parenchyma can be recorded with ultrasound at frequencies of 4 Mc./sec. when the skull is about 1 mm. thick, and at frequencies of 2 Mc./sec. when the skull is about 3 mm. thick.

B. Method

Since the publications of Leksell (1955,

1958) and Jeppsson (1961), the echoencephalographic method has become widely used, but the development of the examination technique has been slow. Thus for paediatric purposes, where there is the most urgent need for a simpler and safer technique than neuroradiological methods for cerebral diagnosis, the method has not been modified greatly, although the practical and theoretical problems are much more complicated in children than in adults. An echoencephalographic method was therefore developed specially for measuring ventricular size in infants, taking into account some of the difficulties arising from the physical properties of ultrasound (Sjögren 1967*b*); a brief summary of this method is presented here.

A Siemens echo-encephalograph (Krautkrämer system), modified by Elema-Schönander, Solna, Sweden, was used. The patient lay in the supine position—considerable intracranial displacement may occur if the patient is turned to the lateral position. For the examination of infants, probes of 4 Mc./sec. and 10 mm. diameter were used, and for older children those of 2 Mc./sec. and 24 mm. diameter. Liquid paraffin was used as a contact medium between the probe and the head; poor contact may reduce the reliability of the examination.

For recording the lateral ventricle echoes, the probe was held against the head 2–5 cm. above and as a rule slightly in front of the external auditory meatus (test point); and for recording a midline echo from the third ventricle it was held a few cm. in front of and slightly below the test point.

The echoencephalographic examination (Fig. 2, Dx and Sin) was performed from two congruent points in the temporal region, and the diameter (D, Fig. 2) between the two points was measured ultrasonically by the transmission method —as the midline control (Mc) distance (D/2) multiplied by two, see Fig. 2. Thereafter a diagram was constructed in which two parallel vertical lines were drawn at a distance of the diameter, these lines symbolizing the right (1, Fig. 2) and left (3, Fig. 2) external contours of the patient's head; line 2 (Fig. 2) represents the geometrical midline of the head.

From the echoencephalograms (Dx and Sin, Fig. 2), the distances from the initial complex to the midline, the lateral ventricle and the bottom echoes were measured and marked in the diagram; the measurement values from the right-sided echoencephalogram (Dx) were marked in horizontally from line 1 (symbolizing the right side of the head), and those from the left-sided echoencephalogram (Sin) were marked in from line 3 (symbolizing the left side of the head, see Fig. 2).

The lateral ventricle echo was defined as that echo which delimited an echo-free zone (from the CSF and which remained echo-free at maximal amplification of the apparatus), which in turn was divided medially by the midline echo. The small echoes between the lateral ventricle echo and the bottom echo were called '*parenchymal echoes*'.

After marking these in the diagram, a schematic picture of a tomogram (in the antero-posterior projection of the temporal region of the head) was seen where the marks for the echoes mentioned above indicated the position of the cerebral midline structures, the lateral wall of the lateral ventricles and the inner surfaces of the superficial structures (skin, skull bone, etc.), respectively.

The distance (T, Fig. 2) between the two marks for the distal lateral ventricle echoes in the two echoencephalograms respectively was measured and expressed in relation to the diameter (D) as an index ($I = T/D$); this index value multiplied by 100 gave the summarized width of the ventricles as a percentage of the diameter

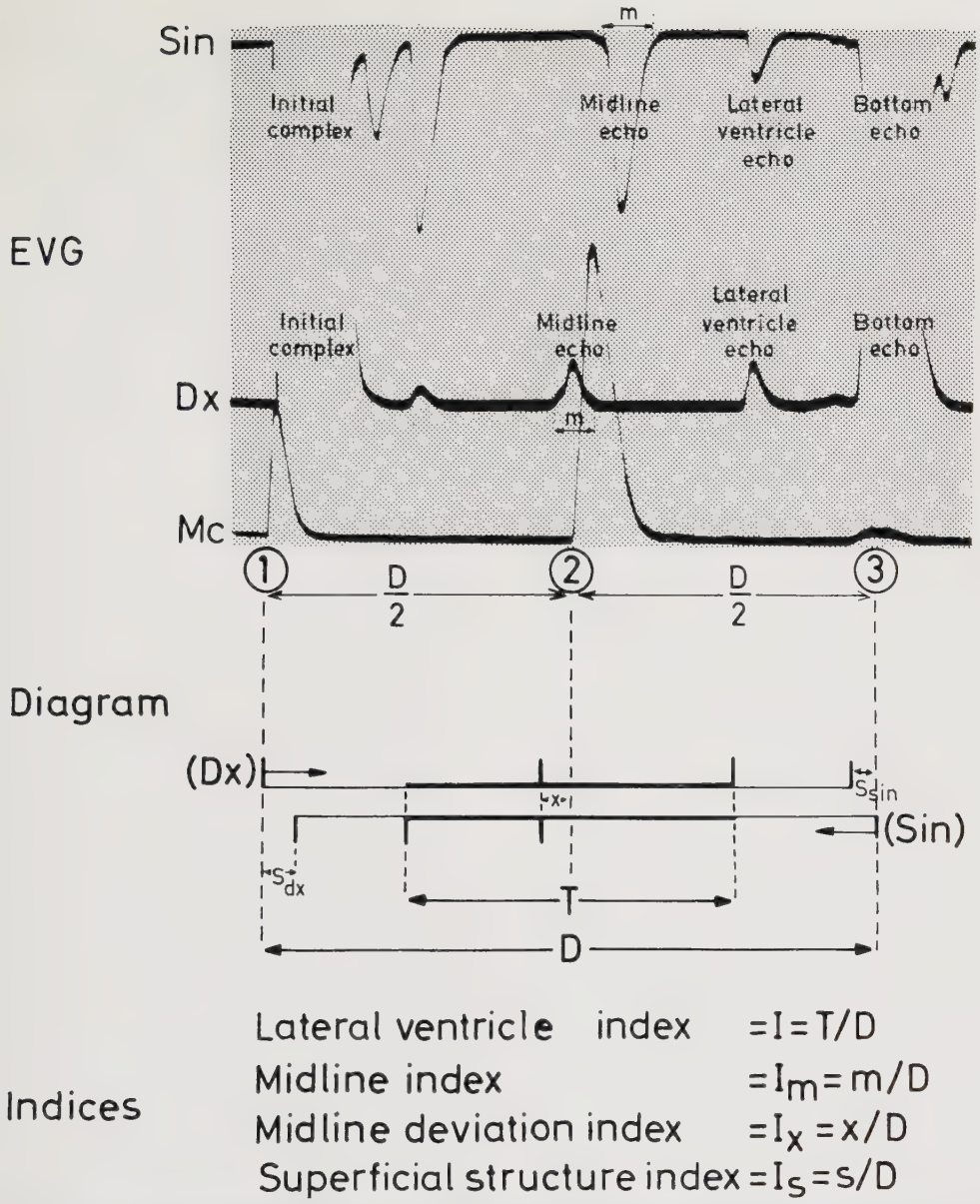


Fig. 2. An echoventriculogram (EVG) within the grey field, where Mc represents the midline control, Dx an echoencephalogram from the right and Sin one from the left test point. The graphical representation and index calculation are explained in the text.

of the head; the more dilated the lateral ventricles, the higher the values of the index.

The width of the midline echo (m, Fig. 2) in an echoencephalogram recorded over the projection of the third ventricle was measured and also expressed in relation to the diameter of the head as a midline index (I_m = m/D).

After each echoencephalographic examination the tracing in the oscilloscope was observed while the probe was being

moved along the sides of the head ('scanning' with the A-scan equipment) and also while the probe was held in fronto-occipital and occipito-frontal directions; when this procedure produced any 'abnormal' echoencephalograms, photographic recordings were made, including a midline control (in order to obtain the external cranial diameter) from the same sites on the head.

Comment

To obtain measurements of length by the ultrasonic echo method, ideal echoes—*i.e.*, those rising practically at right angles to the time axis—are desirable. In calculating the lateral ventricle index, the distal lateral ventricle echo was used because of its focusing properties (see above); it was only in children whose proximal lateral ventricle echo was the only one recordable that this echo was used for the index calculation. It is often impossible to obtain any ideal echoes from intracranial structures, particularly in infants with small, curved and irregularly shaped heads. However, the diameter of the head can be accurately determined ultrasonically. It seems reasonable, therefore, to believe that the method described above can eliminate the sources of error inherent in the conventional technique, where distances are measured between two more or less ideal echoes from intracranial structures.

The intracranial anatomy can be visualised better from a diagram than from separate echoencephalograms. The diagram also enables a direct comparison to be made with cerebral pneumograms, and makes it unnecessary either to convert the echoencephalographic measurements to centimetres, which would increase any errors present, or to correct the pneumographic measurements for the divergent beam direction at the X-ray examination. It seems likely, therefore, that the results of the present echoencephalographic method will be more closely correlated with the results of cerebral pneumography than those of other echoencephalographic methods.

By using the diameter of the head as a reference it is possible to evaluate echoencephalograms obtained from surfaces of the head from which no midline echo could be recorded. It seems reasonable to claim, therefore, that this method could also be used in the diagnosis of cerebral malformations in infants. In infants whose heads are continuously growing a relative estimate of ventricular size seems to be more valuable than an absolute figure, especially in follow-up examinations. In a hydrocephalic with an enlarging skull and expanding ventricles, a fall in the lateral ventricle index from one examination to another shows that the hydrocephalus is arrested, whereas a rise in the index reveals a progressive hydrocephalus at the cost of the cerebral parenchyma, which may mean that the cranial circumference remains unchanged in successive measurements.

The graphic representation and calculation of indices are no more time-consuming than measurements made directly on the echoencephalograms and the calculation of ventricular width in general measurement units. The diagram also provides an extra check on the reliability of recorded echoes in the echoencephalograms from each side of the head. In the diagram, the marks for the midline echoes from the two echoencephalograms, and the marks for the distal lateral ventricle echo from one echoencephalogram and for the proximal lateral ventricle echo from the other should be located on the same verticals. Moreover, echo-free zones and parenchymal echo-bearing zones, if reliable, should be located above one another in the diagram.

C. Comparison between Echoencephalography and Cerebral Pneumography in Measuring Ventricular Size

Several authors have considered it possible to determine the ventricular width by echoencephalography (see references above). However, the few systematic comparisons made between echoencephalography and cerebral pneumography have not shown conclusively that echoencephalography is reliable for determining the size of the ventricles in any given patient. Thus, in Lithander's study (1961), the lateral ventricle echo was found to be situated more laterally than normal in only 6 out of 11 patients with hydrocephalus. Uematsu and Walker (1967) demonstrated ventricular enlargement by echoencephalography in 57 out of 64 patients shown by pneumography to have 'enlarged ventricles' and also in 7 patients who were pneumographically normal. From a series of 63 patients Mikkelsen (1967) concluded that 'only severe central atrophy in children can be diagnosed with certainty'. In 30 hydrocephalic patients, West (1967) reported 'fairly good agreement between the results obtained by the two methods', although differences as high as 47 per cent were reported.

In a comparative study between cerebral pneumography and the echoencephalographic method described above (Fig. 3), there were neither any false-positive or any false-negative reports of dilated lateral or third ventricles; the correlation between the echoencephalographic lateral ventricle and midline indices from the EVG and similar indices calculated from the pneumograms was good (Fig. 4); the correlation coefficient for dilated lateral ventricles was 0·8 and for third ventricles 0·7. The study also showed that echoencephalography is a reliable method for differentiating between normal and dilated ventricular systems (lateral and third) in infants and (third only) in children. The study also revealed that the echoencephalographic method is not reliable for determining the exact widths of normally sized lateral ventricles, especially in older children (Fig. 4). The results show that the method provides an exact estimate of the size of the lateral ventricles in hydrocephalics, the echoencephalographic values being probably more accurate than those based on gas insufflation and X-ray examination. These results were obtained in 56 out of 200 EVG-examined children, 42 of them infants and 14 older children up to 14 years of age, where cerebral pneumography had revealed 'normal' (17 patients) or symmetrically dilated (39 patients) lateral ventricles (Sjögren *et al.* 1968*a*).

Comment

The results from the latter comparative study are far better than from the former studies; this is in accordance with the assumptions in the methodological discussion above. This study was, however, performed in retrospect and in half the cases the pneumographic index values had to be calculated approximately in order to determine the ventricular width for the same region of the ventricular system as was examined echoencephalographically. Preliminary results form a prospective study (Sjögren *et al.*) show that the correlation is even better when these approximations for the pneumographic calculations are eliminated.

In some of the older children with thick skull-bones, it was not possible to record lateral ventricle echos, which is in accordance with the physical calculations: skull bones 3 mm. or more thick absorb too much altrasound for detectable echoes to be recorded from the interface between the cerebral parenchyma and the CSF.

The correlation between the two methods was not very good in patients with normal or slightly dilated lateral ventricles (Fig. 4, $I_{PNEUMO} < 0{\cdot}45$); this is also in agreement

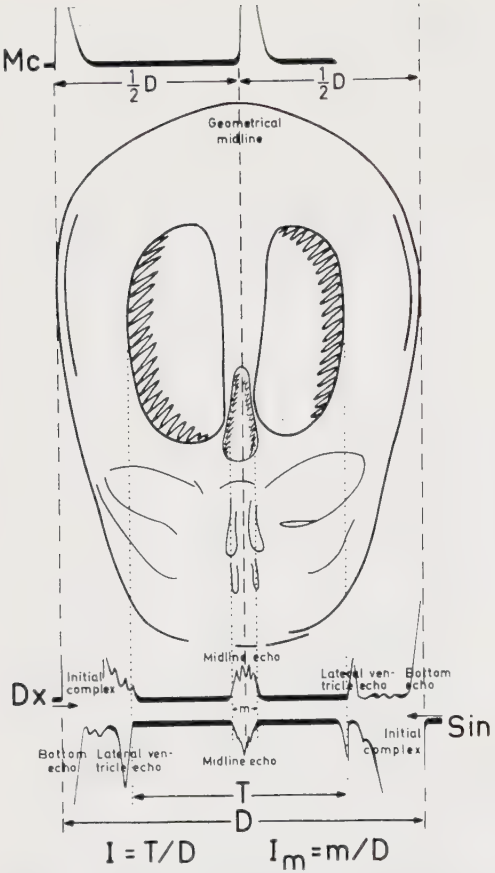


Fig. 3. Schematic pneumogram compared with enlarged schematic EVG, where Mc is the midline control, Dx the echoencephalogram from the right, and Sin an inverted echoencephalogram from the left temporal region. The position of the lateral ventricle echoes correspond to the lateral surfaces of the lateral ventricles, and the echo-free zones to the widths of the lateral ventricles seen in the pneumogram. The position of the cerebral parenchyma in the pneumogram corresponds to small parenchymal echoes in the echoencephalograms (between the lateral ventricle echoes and the bottom echoes).

with the above assumptions (Fig. 1 C and D): a normal lateral ventricle with a small curvature radius and an irregular surface gives rise to a multi-spiked echo of low amplitude, which does not allow accurate length determination; in such cases the distribution of parenchymal echos and the absence of an enlarged echo-free zone revealed, though indirectly, non-dilated ventricles.

In cases of infantile hydrocephalus, the correlation between the two methods was very good; the lateral ventricle echoes, delimiting an enlarged echo-free zone, were ideal in most cases, in agreement with the above assumptions (Fig. 1 B).

Thus, the echoencephalographic method seems to be reliable in determining the ventricular width in infants and children, provided the examination is performed with a method adapted for its purpose and with knowledge of its limitations and difficulties.

D. Comparison between Echoencephalography, Cerebral Pneumography and Post-Mortem Examination in Infants with Cerebral Malformations

In the above-mentioned 200 neuropaediatric patients, examined by echoencephalography, cerebral pneumography and, in some cases, post-mortem examination, cerebral malformations were revealed in 14 cases (Sjögren *et al.* 1968*b*).

In 13 of these, a correct diagnosis was obtained by echoencephalography in accordance with the findings of cerebral pneumography and/or post-mortem examination. Six of these patients had hydrocephalus and asymmetrical cerebral malformations. In 3 patients the diagnosis of hydranencephaly was made by echoencephalography in a few minutes; almost totally echo-free zones were recorded intracranially in all directions of the probe. A further patient had hydrocephalus and agenesis of the corpus callosum; another had hydrocephalus and a partly underdeveloped ventricular system; and a third had Dandy-Walker syndrome, with an enormously dilated fourth ventricle (Fig. 5 a and b).

In one patient, pneumographically normal, echoencephalography revealed porencephalic cysts (Fig. 6), in accordance with the subsequent post-mortem examination; in the cerebral parenchyma, bi-

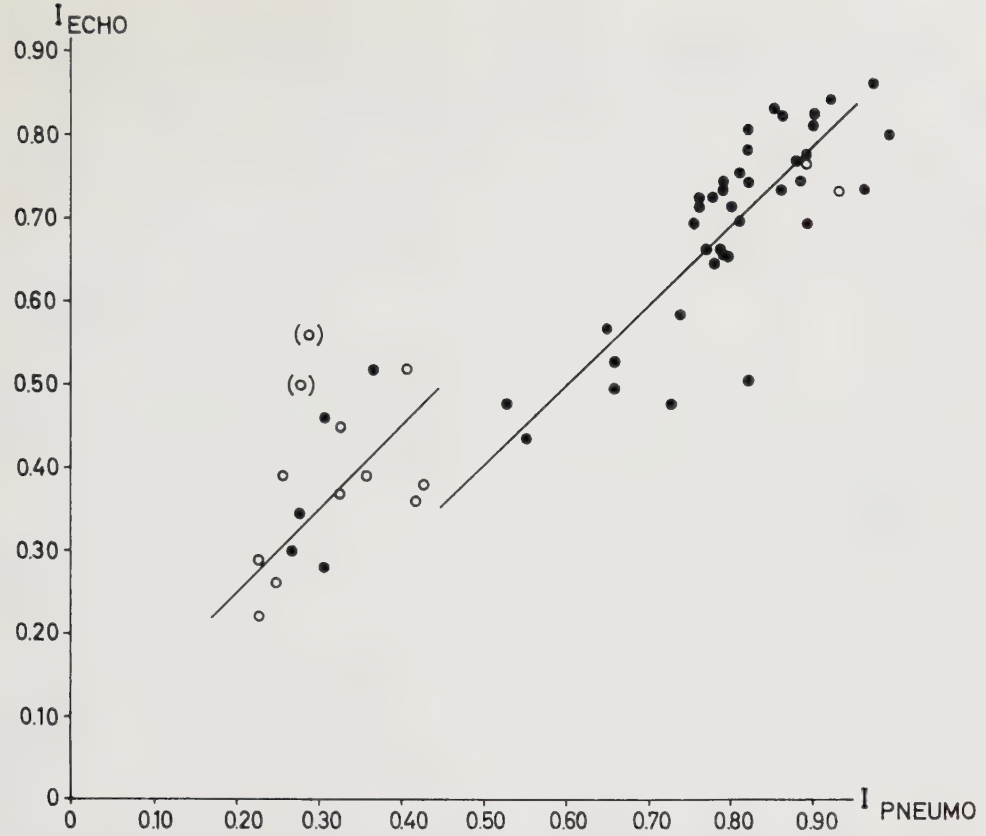


Fig. 4. The diagram shows: (1) a good correlation ($\rho = 0{\cdot}8$) between the echoencephalographic lateral ventricle index (I_{ECHO}) and the pneumographic index (I_{PNEUMO}) in 39 patients with moderately to greatly dilated lateral ventricles ($I_{PNEUMO} > 0{\cdot}45$), of whom all but 2 were under a year old (filled circles) (2) a low correlation ($\rho = 0{\cdot}44$) between the I_{ECHO} and the I_{PNEUMO} in 17 patients with normal to slightly dilated ventricles, 12 of whom were over a year old (unfilled circles).

laterally in the parieto-occipital region, there were fluid-filled spaces which communicated with neither the ventricles nor the subarachnoid spaces, and were therefore not detectable by cerebral pneumography.

In the final patient, no absolutely correct diagnosis was made either by cerebral pneumography or by echoencephalography; the patient had spina bifida cystica, Arnold-Chiari malformation and highly viscous intraventricular contents; therefore the gas injected for cerebral pneumography was almost immobile; echoencephalography produced no lateral ventricle or midline echoes because the differences in acoustic impedance between the intraventricular contents and the cerebral parenchyma were too small; however, it was possible to predict correctly (according to subsequent post-mortem examination) the thickness of the cerebral parenchyma on both sides of the head, by the distribution of the parenchymal echoes. In none of these 200 patients, apart from the above-mentioned series, did echoencephalography reveal signs of cerebral malformations.

Comment

The results show, firstly, that the echoencephalographic method described is also

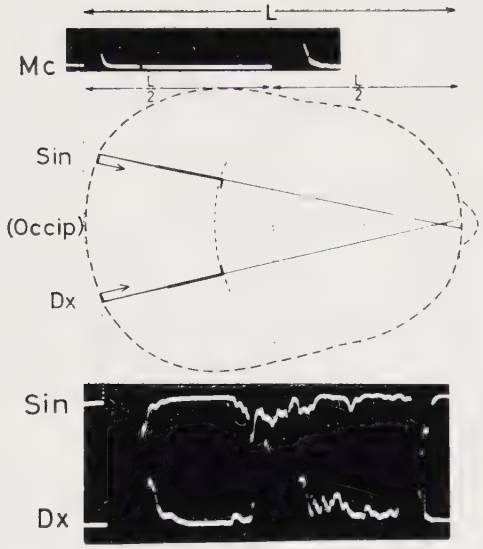
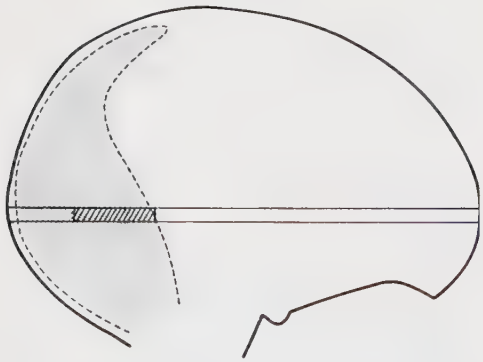


Fig. 5. Graphic representation of the findings at echoencephalography (a) and cerebral pneumography (b) in a patient with an occipital fluid-filled cyst (Dandy-Walker syndrome).
(a) Mc is a midline control in the occipito-frontal direction and L represents the longitudinal cranial diameter (twice the midline control distance, $\frac{L}{2}$); the diagram with the contours of the head, seen from above, was constructed from L and ultrasonically determined diameters of the head bitemporally and biparietally, as well as sketches of the patient's head at the time of the examination. The arrows indicate the pathway of ultrasound at the echoencephalographic examinations from the left and right occipital region. On the echoencephalograms, Dx and Sin, an echo-free zone can be seen occipitally between the initial complex and a series of parenchymal echoes.



(b) The grey field symbolises the air-containing occipital cyst on the pneumogram, which also revealed normal third and lateral ventricles; the horizontal parallel lines indicate the pathway of ultrasound and the cross-hatchings show the echo-free z one seen on echoencephalography.

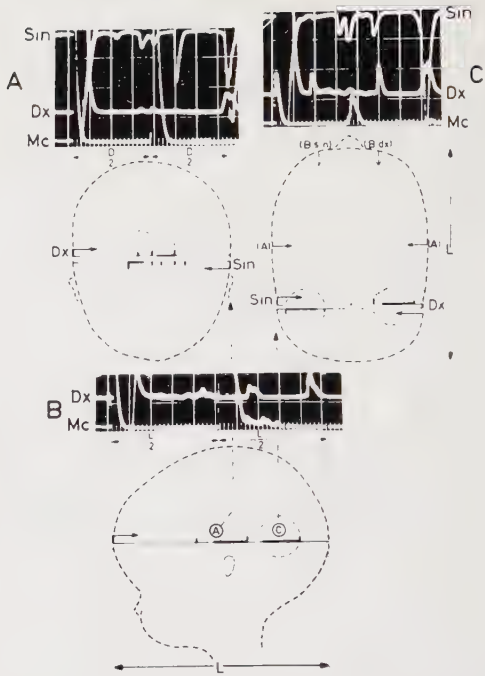


Fig. 6. Graphic representation of echo- encephalographic findings in a boy with porencephalic cysts parieto-occipitally. Frontal view (A), the head seen from the left side (B) and from above (C).
A = an EVG from the temporal region, showing a normal ventricular system.
B = recordings in the fronto-occipital direction, where Mc = a midline control and the double midline control distance (L) corresponds to the longitudinal diameter of the head, Dx = an echoencephalogram from the right frontal region. The beam direction is indicated by an arrow in diagram C also, showing echo-free zones, indicated by thick lines, in the midplane (from the lateral ventricles) and also parieto-occipitally (from a porencephalic cyst) immediately before the bottom echoes.
C = recordings in the bioccipital direction, where Mc = a midline control and the double midline control distance gives the diameter of the enlarged occipital region; Dx and Sin = echoencephalograms from the right and left side, respectively, showing echo-free zones just before the bottom echoes.

reliable for diagnosing some gross cerebral malformations in infants, and secondly, that the measurement techniques—with the outer margins of the ultrasonically determined diameter of the head as reference points—can be used for practical clinical purposes. Its limitations—namely, that only structures running almost parallel

to the surface of the head, where the probe was applied, can be detected—make it possible to obtain only a rough determination of the form and distribution of cerebral malformations and the ventricular system; for a more accurate determination, cerebral pneumography is needed. In cases requiring cerebral pneumography, however, echoencephalography may still be of great value; when cerebral pneumography reveals 'cerebral expansivities', echoencephalography may show whether these are cystic, when they will give rise to echo-free zones from the fluid inside the cyst, or tumorous, when they will produce multiple atypical 'tumour echoes'.

In patients with, for example, asymmetrical lateral ventricles, a partly underdeveloped ventricular system or extracerebral cysts (see Fig. 5), it is possible to determine by echoencephalography the most suitable place for puncture for gas insufflation before ventriculography.

In many cases cerebral pneumography can be avoided—for example, in patients with hydranencephaly, where a correct diagnoses is possible by means of echoencephalography and where a further determination of the size and distribution of possible cerebral remnants usually does not change the further clinical treatment. Finally, echoencephalography makes it possible to diagnose malformations which are not detectable by neuro-radiological examinations—*e.g.*, some intracerebral fluid-filled spaces (see Fig. 6).

E. Echoencephalography in Normal Infants and Children

Echoencephalography was performed in 100 children (Sjögren 1968): 20 newborn babies (under 1 week), 60 infants (between 5 weeks and 12 months) and 20 older children (1–5 years). In all of these the midline echo was recordable, and in 88 cases it was located on the geometrical midline; in 12 a small midline deviation was noted, in no case exceeding 2 per cent of the diameter of the head. The midline index (I_m) varied between 0·03 and 0·08—*i.e.*, the width of the midline echo did not exceed 8 per cent of the diameter of the head except in one case with marked hypertelorism and a midline index of 0·10.

Parenchymal echoes were recorded in all the children of this series, bilaterally in all the infants under 5 months of age, as well as in 26 of the remaining 55; in 29 infants and children the parenchymal echoes were recordable only proximal to the midline echo while the echoencephalogram between the distal lateral ventricle echo (when recordable) and the bottom echo represented an almost echo-free zone.

In all cases in which they were recordable, the lateral ventricle echoes were of low amplitude, and they were mostly multi-spiked; any echo-free zones from the intracranial fluid were hardly recordable.

In all infants of 12 weeks of age or less (40 cases), lateral ventricle echoes were recorded and lateral ventricle indices were calculated; in the infant group below 10 months of age (67 cases) the midline echo was recordable in all except 3. For the age-group 10 months to 2 years, the lateral ventricle echo was recordable in 11 out of 23 cases. The lateral ventricle echo was recordable in only one of the 10 children over 2 years.

The lateral ventricle index was significantly higher for the newborn babies ($I = 0{\cdot}30 \pm 0{\cdot}03$) than for the rest of the material ($I = 0{\cdot}26 \pm 0{\cdot}03$).

Comment

The number of cases where any 'midline deviation' was recorded was small, and the extent of the deviation was also small (≤ 2 per cent of the diameter of the head); for infants and children with comparatively

large variations in cranial size it seems more accurate to express the values for any midline deviation as a percentage of the cranial diameter than in absolute values; in normal infants and children midline deviations are small and one of 3 per cent or more of the diameter of the head should be regarded as pathological (see Jeppson 1961).

In only 1 of the 10 children aged 2 years and over and with comparatively thick skull bones could unmistakeable lateral ventricle echoes be recorded, which is in good agreement with the physical calculations mentioned above: skull bones that are 3 mm. or more thick absorb too much ultrasound for detectable echoes to be obtained from the interface between cerebral parenchyma and CSF. The configuration and low amplitude of the lateral ventricle echoes recorded agree with these assumptions (see Fig. 1, C and D) and cannot be accurately measured, which also agrees with the findings in normal patients in the comparative study between echoencephalography and cerebral pneumography. The difference between the values for the lateral ventricle index in newborn babies and older children could possibly be due to the decompression of the head and a relatively smaller diameter of the head immediately after birth.

Discussion

There has long been a need in paediatrics for a harmless and simple method of recording the intracranial anatomy, and particularly variations in the size of the ventricular system. Since the introduction of more active treatment of neuropaediatric patients—*e.g.*, shunt operations in expansive hydrocephalus—this need has become even more urgent.

With the introduction of echoencephalography such a method seemed to have been found. However, after many 'trials and errors', this 'harmless, cheap, simple and quick' method was not always found to be simple or safe, partly because the difficulties and limitations of the method were not always appreciated.

All operators have had no difficulty in finding a multiplicity of echoes wherever they placed the probe on the skull and at whatever angle it was directed; the difficulty is to identify the echoes obtained.

The midline echo has certain rather definite characteristics which distinguish it from other structures; it is usually the echo of highest amplitude seen on the echoencephalogram from the temporal region, it pulsates in tune with the heart beat and is usually double-peaked; in small infants it is often broad based.

In cases of hydrocephalus the lateral ventricle echo is usually also of high amplitude, single-peaked and pulsating, and delimits laterally an echo-free zone. On scanning (with the A-scan equipment) lateral ventricle echoes (delimiting an echo-free zone) could be obtained from several points on the head. By combining these echoes it is possible to visualize the shape of the ventricles in three dimensions.

If it is to be a reliable method of examination—comparable to X-ray examinations—the echoencephalographic technique must be modified so that it can be represented in graphical form, and this graphic representation must contain built-in guarantees that the echoes recorded are the midline and lateral ventricle echoes and nothing else (White 1966).

The results obtained with echoencephalography correlate well with those of cerebral pneumography, and this graphic representation also proved reliable when echoencephalography was performed on the surface of the head, where no midline echo could be recorded.

The upper limit for the lateral ventricle index in normal infants was shown to be

0·33 (or one-third of the diameter of the head). For clinical purposes I have expressed index values between 0·33 and 0·40 as 'a slight increase in the lateral ventricle index', values between 0·41 and 0·50 as 'a slight increase in the width of the lateral ventricles', values between 0·51 and 0·70 as 'moderate hydrocephalus' and index values over 0·70 as 'advanced hydrocephalus'.

SUMMARY

The energy transferred during an echoencephalographic examination is considerably below the level at which harmful effects may occur, even in small infants.

The interface between cerebrospinal fluid and brain parenchyma can be recorded by echoencephalography provided that the skull is not more than 3 mm. thick.

Echoencephalography, modified according to measurement of the ventricular size and represented graphically, is a reliable method in the differential diagnosis between normal and dilated ventricular systems, fairly reliable in evaluating the size of the ventricles in infantile hydrocephalus and in follow-up examinations of such patients, and is suitable for a screening diagnosis before neuroradiological examinations. It may also be helpful in choosing the puncture site for ventriculography in patients with asymmetrical ventricular systems, in determining whether cerebral expansions, observed by cerebral pneumography, are solid tumours or fluid-filled cysts, and in diagnosing some gross cerebral malformations and intracerebral cysts.

Echoencephalographic examinations of normal infants and children show that the lateral ventricles in newborn babies are somewhat wider than in older children, and that the upper limit for the body of normal lateral ventricles is 1/3 of the diameter of the head.

RÉSUMÉ

Echo-encéphalographie dans la mesure de la taille des ventricules des enfants

L'énergie dissipée au cours d'un écho-encéphalogramme est bien inférieure à celle qui pourrait produire des effets nuisibles, même chez les tout petits enfants.

La frontière entre le liquide céphalo-rachidien et le parenchyme cérébral peut être enregistrée par écho-encéphalographie à condition que l'épaisseur du crâne ne dépasse pas 3 mm. environ.

L'écho-encéphalographie, modifiée en vue de la mesure de la taille des ventricules et traduite graphiquement, est une méthode sure pour différencier les systèmes ventriculaires normaux et dilatés; c'est une méthode suffisamment précise pour évaluer la taille des ventricules dans l'hydrocéphalie infantile et pour suivre les hydrocéphales; elle convient aux diagnostic de triage avant les examens neuroradiologiques. Elle peut également servir à choisir l'emplacement de la piqûre pour la ventriculographie chez les patients ayant des systèmes ventriculaires assymétriques, elle sert encore à déterminer si les expansions cérébrales observées par pneumographie cérébrale sont des tumeurs solides ou des kystes liquidiens, et à diagnostiquer quelques déformations cérébrales importantes et quelques kystes intracérébraux.

Les examens écho-encéphalographiques des nourrissons et enfants normaux montrent que la largeur des ventricules latéraux chez les nouveaux-nés est un peu plus grande que chez les enfants plus vieux, et que la limite supérieure pour le corps des ventricules latéraux normaux est 1/3 du diamètre de la tête.

ZUSAMMENFASSUNG

Echo-Enzephalographische Messung der Ventrikulärgrösse von Kindern

Die während einer echo-enzephalographischen Untersuchung angewandte Energie ist weit schwächer als die Stärke bei der schädliche Wirkungen selbst bei ganz jungen Kleinkindern auftreten könnten.

Die Zwischenschicht der zerebrospinalen Flüssigkeit und des Gehirn-Parenchyms kann echo-elektroenzephalographisch aufgenommen werden, vorausgesetzt dass die Schädeldicke etwa 3 mm oder weniger ist.

Echo-Enzephalographie, nach der Messung der Ventrikulärgrösse modifiziert und graphisch dargestellt, ist eine zuverlässige Methode bei der Differential-Diagnose zwischen normalen und erweiterten Ventrikulärsystemen, recht zuverlässig bei der Grössen-Einschätzung der Ventrikel bei infantilem hydrocephalus und bei Nach-Untersuchungen hydrozephalischer Patienten, und ist auch geeignet als Vorwahls-Diagnose vor neuroradiologischen Untersuchungen. Sie kann auch von Nutzen sein bei der Wahl der Punktionsstelle für Ventrikulographie bei Patienten mit asymmetrischen Ventrikulärsystemen; bei der Feststellung, ob mithilfe von Zerebral-Pneumographie beobachete zerebrale Erweiterungen solide Tumore oder mit Flüssigkeit gefüllte Zysten sind; wie auch bei der Diagnose einiger schwerer Zerebralmissbildungen und intrazerebraler Zysten.

Echo-enzephalographische Untersuchungen normaler Kleinkinder und Kinder zeigen dass die Weite der lateralen Ventrikel von Neugeborenen etwas grösser ist als bei älteren Kindern, und dass der Höchst-Grenzwert für das Ausmass normaler lateraler Ventrikel 1/3 des Kopf-Diameters ist.

RESUMEN

Ecoencefalografía en la pediatría, con respeto sobre todo a la medición del tamaño ventricular

La energía transferida durante una exploración ecoencefalográfica es muy debajo del nivel al que efectos dañosos pueden ocurrir, aun en lactantes pequeños.

Es posible registrar la interfase entre el líquido cefalorraquídeo y el parénquima cerebral por medio de ecoencefalografía, con tal que el cráneo tenga unos 3 mm. o menos de espesura.

La ecoencefalografía, modificada según las medidas del tamaño ventricular y representada en forma de un gráfico, es un método digno de confianza para el diagnóstico diferencial entre sistemas ventriculares normales y dilatados, bastante digno de confianza para la valoración del tamaño de los ventrículos en la hidrocefalia infantil y en exploraciones sucesivas de hidrocéfalos, y sirve como examen preliminar antes de exploraciones neuroradiológicas. Puede también ayudar en la elección de un sitio de puntura para la ventriculografía de enfermos que tienen un sistema ventricular asimétrico, en determinar si expansiones cerebrales observadas por neumografía cerebral son tumores sólidos o quistes llenos de líquido, y en diagnosticar algunas malformaciones cerebrales graves y quistes intracerebrales.

Exploraciones ecoencefalográficas en lactantes y niños sanos muestran que la anchura de los ventrículos laterales en recién nacidos es un poco más que la de niños mayores, y que el límite superior para el cuerpo de ventrículos laterales normales es 1/3 del diámetro de la cabeza.

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ACKNOWLEDGEMENTS

I am deeply grateful to all who have cooperated in the present work, which was carried out at the Department of Paediatrics, University Hospital, Uppsala.

My thanks are due especially to Professor Bo Vahlquist, head of the Department, for stimulating my interest in research and for making this interest grow, and for his constant encouragement throughout the work;

to Associate Professor Bengt Hagberg, head of the section of Paediatric Neurology at the Department, who with encouraging confidence referred patients for my examinations, introduced me in the fascinating fields of paediatric neurology and clinical research work, and showed stimulating interest in the investigations;

to Associate Professor Stig Jeppsson, head of the Department of Neurosurgery at the Regional Hospital, Linköping, and world specialist and pioneer with regard to the use of ultrasonic echo in medical diagnosis, for teaching me personally from his vast experience, for devoting much of his valuable time to stimulating discussions, and for his encouragement and positive criticism of my work;

to my husband Håkan Sjögren, Assistant Professor at the Department of Physics at the Royal Institute of Technology, Stockholm, for — without any knowledge of earlier studies of ultrasound in medical diagnosis — giving me the initiative for attempting examinations with ultrasonic echo in diagnosing infantile hydrocephalus, for teaching me about the physical properties of ultrasound and general scientific methods and for his encouraging and critical discussions;

to Professor Herman Lodin, head of the Department of Diagnostic Radiology, University Hospital, Uppsala and Dr. Kjell Bergström at the same Department, for valuable collaboration and stimulating discussions during the correlation studies and for their positive interest in echoencephalography in children — leading to the introduction of echoencephalography as a routine method in neuropaediatric patients to the X-ray Department;

to Professor Karl Axel Ekbom and Assistant Professor Per Olov Lundberg at the Department of Neurology and Associate Professor Karl Erik Hagbarth, head of the Department of Neurophysiology, University Hospital, Uppsala and his former Assistant Professor Sigfrid Blom (now head of the Department of Neurophysiology, University Hospital, Umeå), for their valuable help and generosity in placing echoencephalographic equipment at my disposal, which meant the start of these investigations in children;

to Associate Professor Gunnar Grotte, head of the Department of Paediatric Surgery, University Hospital, Uppsala, and Dr. Gabriel Reuterskiöld at the same Department, for their permission for and appreciation of echoencephalographic examinations of their patients, and for many stimulating discussions;

to Professor Carl Gemzell, head of the Department of Obstetrics and Gynaecology, for permitting my echoencephalographic examinations of the newborn babies for the »normal material», at his Department;

to Professor Helmuth Hertz, head of the Department of Physics at the Institute of Technology, Lund, Professor Erik Lindgren, head of the Department of Diagnostic Radiology at the Serafimer Hospital, Stockholm, and Associate Professor Lars Olding at the Department of Pathology, University Hospital, Uppsala, for stimulating discussions concerning problems in their respective special fields and for their positive criticism of the relevant parts of the manuscript;

to Assistant Professor Adam Taube, Ph. D., for stimulating discussions and statistical calculations concerning the »normal material»;

to Associate Professors Lars Garby and Andreas Killander at the University Hospital, Uppsala, for valuable discussions and criticism and for their views concerning the disposition of the material in this study.

My warm and sincere thanks go also to the translator, Mrs Maud Marsden for her swift translations — with feeling and understanding — and for teaching me about linguistic nuances;

to Mrs Birgit Häggqvist, whose artistic talent was of great value in the creation of the illustrations;

to Miss Kerstin Sjöberg for accurate and rapid typing and for her ready acceptance of manuscripts, be it evening or Sunday;

to the nurses and other personnel of the University Hospital and Child Welfare Clinics, Uppsala, who with interest, care and understanding helped me in the infant examinations;

and to my children, Lars Håkan and Christina, whose facial contours were used in a number of illustrations in the original papers, and who helped me by their pleasure in following the work to its completion.

Financial support has been gratefully received from the Medical Faculty of the University of Uppsala, the Folke Bernadotte Foundation for Children with Cerebral Palsy, the Bengt and Birgit Hedström Family Donation Fund and from the Gertrude och Ivar Philipsons Stiftelse.

Motto on p. III from »Mild-Moderate Forms
of Protein-Calorie Malnutrition. Symposia
of the Swedish Nutrition Foundation I, Båstad,
August 29—31, 1962.» Edited by Gunnar Blix,
Almqvist & Wiksells Boktryckeri AB, Uppsala 1963.

Price: Sw. kr. 10:—